Operative Techniques in Thoracic and Cardiovascular Surgery

Valve-Sparing Aortic Root Replacement with the Valsalva Graft

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Techniques to preserve the native aortic valve during aortic root replacement have evolved considerably over the last 15 years, largely due to the continued pioneering efforts of Tirone David and Magdi Yacoub. Strictly speaking, full root replacement entails complete replacement of all aortic sinuses and reimplantation of the coronary arteries to the root prosthesis. The valve may be replaced as well, the so-called Bentall procedure, or the valve may be preserved, a procedure known as valve-sparing aortic root replacement. Operative techniques for the latter can be categorized broadly into either remodeling or reimplantation procedures, terms coined by David to denote whether the aortic prosthesis sits atop the valve annulus (remodeling) or contains the entire valve complex within (reimplantation) (Fig. 1) In the early iterations of these procedures, the reimplantation procedure used a straight Dacron tube, which provided anular stabilization but lacked sinuses that could potentially relieve stress on the aortic valve leaflets. The remodeling procedure created neo-aortic sinuses that were theoretically advantageous to leaflet integrity but did not stabilize the annulus. Subsequent modifications of the remodeling procedure buttressed the annulus by suture or prosthetic strips but had mixed results. In recent years, various custom-design prostheses have been described that combine the sinuses of the remodeling procedure with the anular stabilization of reimplantation, with the hope that a more anatomically faithful yet geometrically stable prosthetic root would lead to better long-term valve competence.

The Valsalva graft is a commercially available gelatin-impregnated aortic root prosthesis developed by Ruggero DePaulis of Rome; it can be used in either remodeling or reimplantation procedures. It has three components: a collar with horizontally oriented crimps or pleats, a skirt with vertically oriented pleats that make the sinus segment more compliant, and a long tubular segment with horizontal pleats (Fig. 2). Its dimensions permit a faithful anatomic creation of the aortic root, and laboratory evidence supports the contention that it facilitates valve opening and closure, thereby minimizing leaflet stress and strain. As such it combines the "best of both worlds" of reimplantation and remodeling principles yet is readily available and can be implanted with a reproducible and straightforward technique (*vide infra*).

The Valsalva graft sizes (diameter in millimeters) range from 24 to 34, a range that we believe meets the requirements of nearly all patients who are suitable candidates for valve-sparing procedures. The rare infant who requires root replacement usually has an optimal sinotubular junction (STJ) diameter greater than or equal to 24 mm, whereas adult patients with an optimal STJ of more than 34 mm, in our opinion, are probably not good candidates for valve-sparing root replacement because of extreme leaflet elongation. The graft does, however, permit placement of the commissures just above the "sinotubular ridge" of the graft to accommodate longer leaflets and thus theoretically accommodates larger roots.

An important caveat for handling the graft is that use of an ophthalmic or electrocautery should be avoided unless the graft is wetted. Dry gelatin is flammable. We prefer to work with a dry graft and use scissors.

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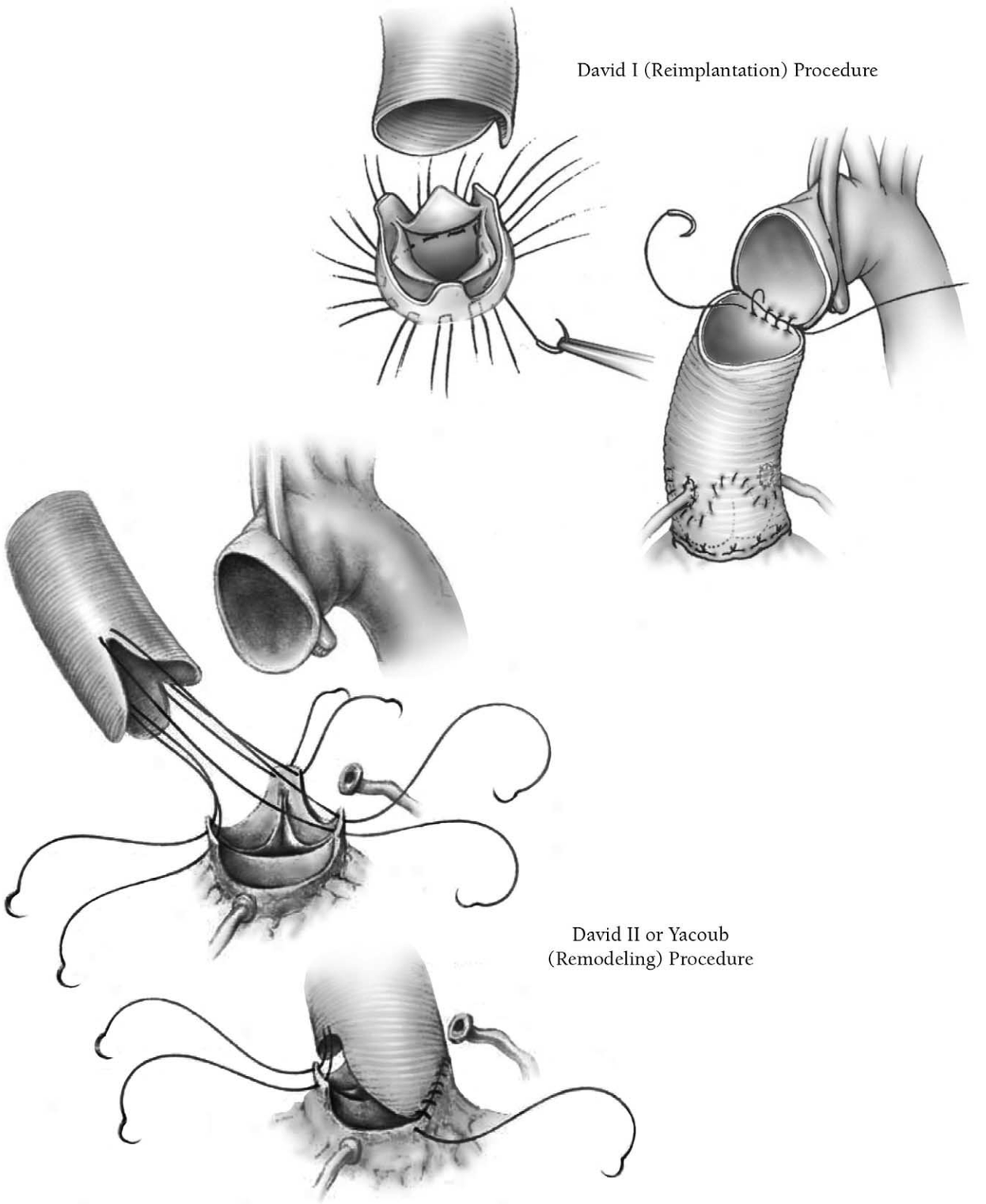

Figure 1 Competing techniques for aortic root reconstruction.

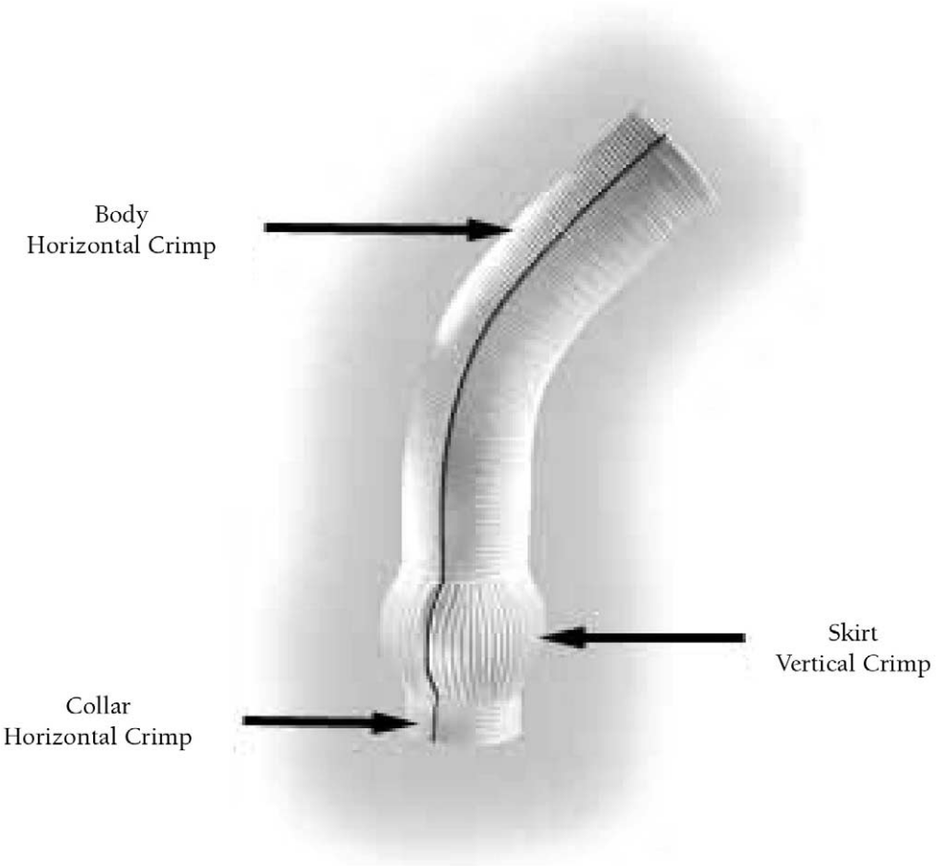

Figure 2 The Valsalva graft is a gelatin-impregnated Dacron graft designed to reproduce the anatomic and physiologic features of the normal aortic root. The collar provides anular stabilization, while the skirt simulates the sinuses of Valsalva.

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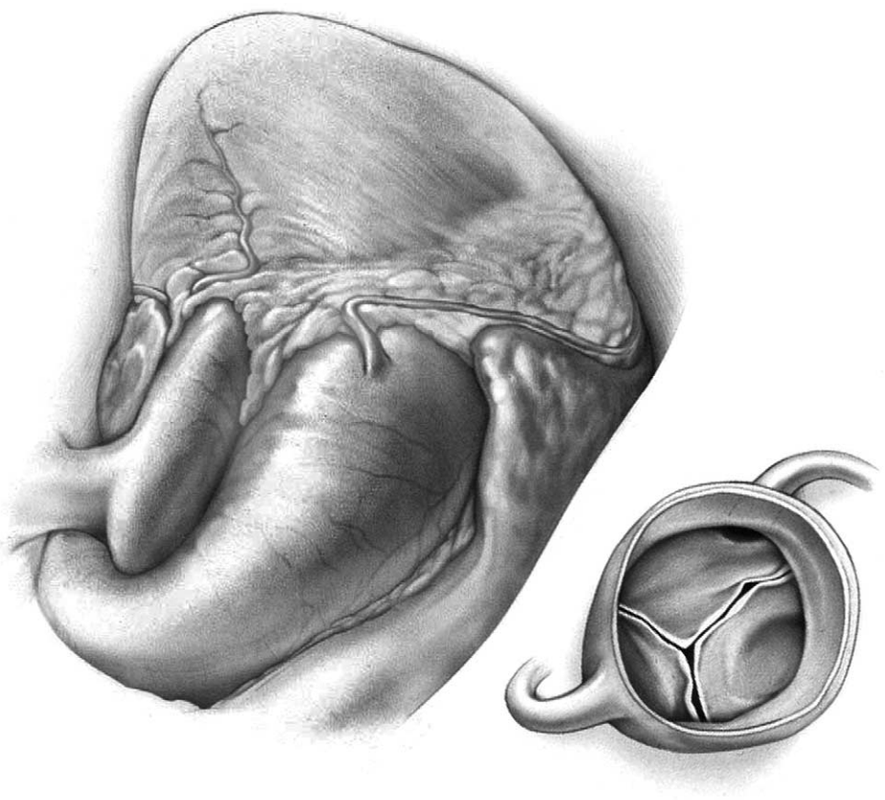

Figure 3 Standard full sternotomy is important for adequate exposure. Aprotinin and intraoperative transesophageal echocardiography are used routinely. We prefer to cannulate the aorta in the proximal arch rather than in the femoral vessels, even in patients with severe connective tissue disorders. Bicaval venous cannulation (in adults, two 24-Fr straight venous cannulae via the right atrial appendage and low right atrial wall) is our routine practice for two reasons. First, the SVC cannula holds the right atrial appendage down and inferiorly improves exposure of the root. Second, we routinely explore the right atrium for patent foramen ovale, which is present in one-third of patients and may be a risk factor for left heart endocarditis from paradoxical bacterial embolism. Caval snares are passed, and a left atrial vent is placed via the right superior pulmonary vein.

Cardiopulmonary bypass with vacuum-assisted venous drainage is begun and the patient cooled to 28°C. Because most of our patients have Marfan syndrome and most have competent aortic valves, cardioplegia may be delivered via the aortic root after cross-clamping. Eight hundred to 1000 mL cold blood cardioplegia is given, and repeat doses of 100 mL are given directly into each coronary ostium via soft Silastic-tipped handheld cardioplegia cannulae every 30 minutes thereafter. Cold topical saline is used for additional myocardial protection.

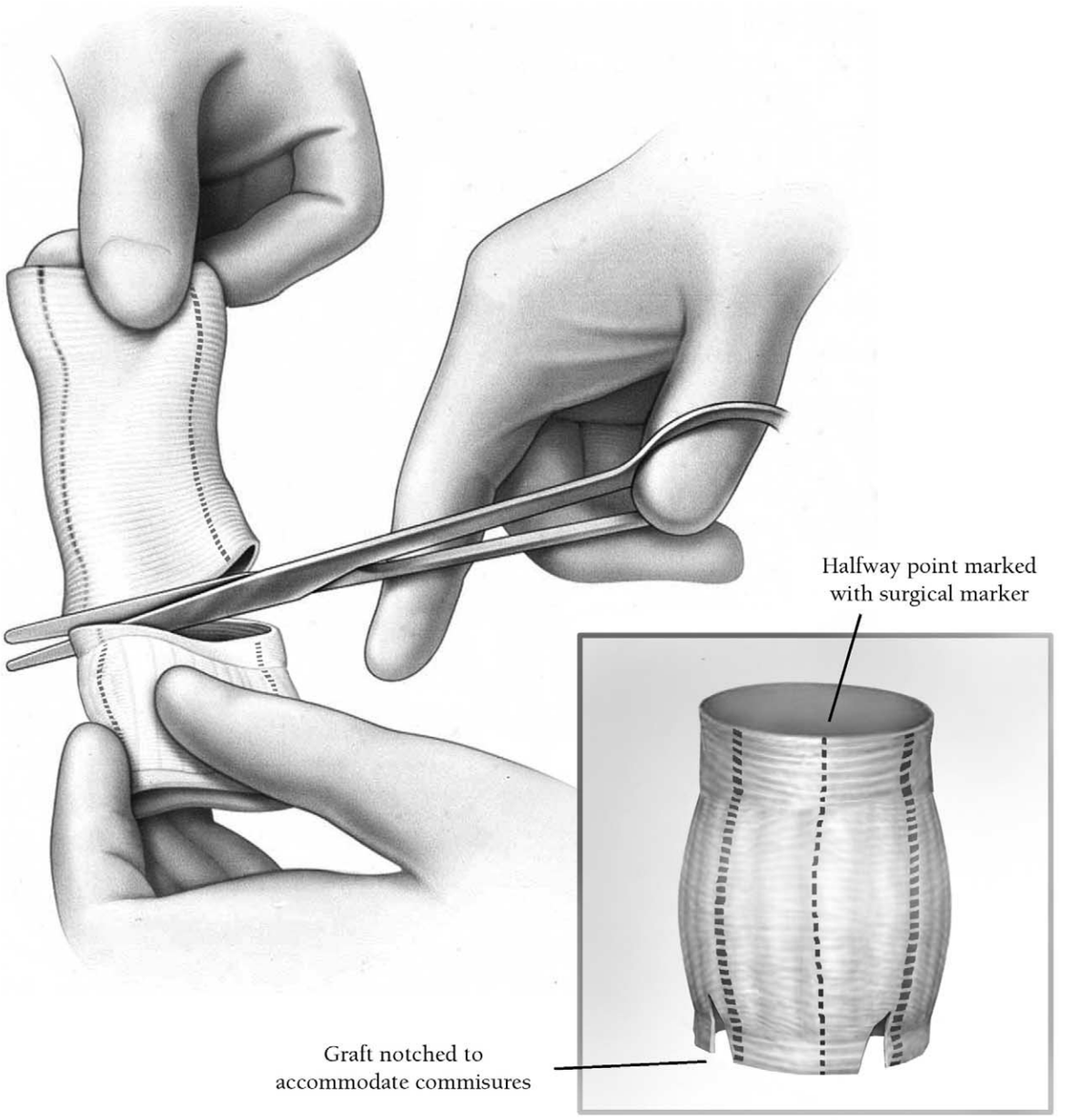

Figure 4 We begin by opening the right atrium, closing the PFO if present, and removing the caval snares after atrial closure. The aorta is transected just above the STJ, and the ascending aorta is excised up to within 1 to 1.5 cm of the aortic cross clamp. Stay sutures of 2-0 silk are placed 4 to5 mm cephalad to the top of each of the three commissures. The root is mobilized by carefully separating the tissue from the undersurface of the right pulmonary artery and right side of the main pulmonary artery, with care to avoid injury to the left main coronary artery. The atrial and epicardial tissue at the base of the noncoronary dissected is dissected away to the level of the annulus, and the fibrous tissue adjacent to the left–right coronary aortic leaflets is separated from the pulmonary artery as low as possible.

At this point, using St. Jude Medical valve sizers and varying the traction on the commissural stay sutures, we make a judgment as to the optimal STJ diameter. Most of our patients have Marfan syndrome with dilated sinuses and competent aortic valves, and our approach has been to preserve, or only slightly reduce, the STJ diameter, to maintain leaflet apposition and valve competence. An ideal diameter is chosen, and 2 to3 mm is added to this number to account for aortic wall thickness because the Valsalva graft will sit outside the root complex. Most adults will receive a 30- or 32-mm graft. We have not measured leaflet length or invoked the formulas reported by other authors. The base of the graft is shortened to about three rings and the distal end to about five rings. Leaving the tubular portion of the graft too long makes suturing the annular and sinus remnant within the graft difficult; if additional length is needed later for the distal end of the graft, it is better to interpose a separate short length of graft.

Three black marks on the graft are conveniently aligned with the commissures. We usually use a surgical marker to make three longitudinal lines that subdivide each of the three "sinus segments" of the graft; these mark the sites of the coronary artery implants but also mark the middle and nadir of each subanular suture. The final preparatory step for the graft is to make a 1-cm notch at the bottom of the graft along the black seams where the graft slides down next to the left–right and the right–noncoronary commissures. At these points, it is sometimes difficult to dissect to a depth level with the nadir of the right coronary sinus without entering the right ventricle. Notching the graft facilitates symmetric low seating of the graft.

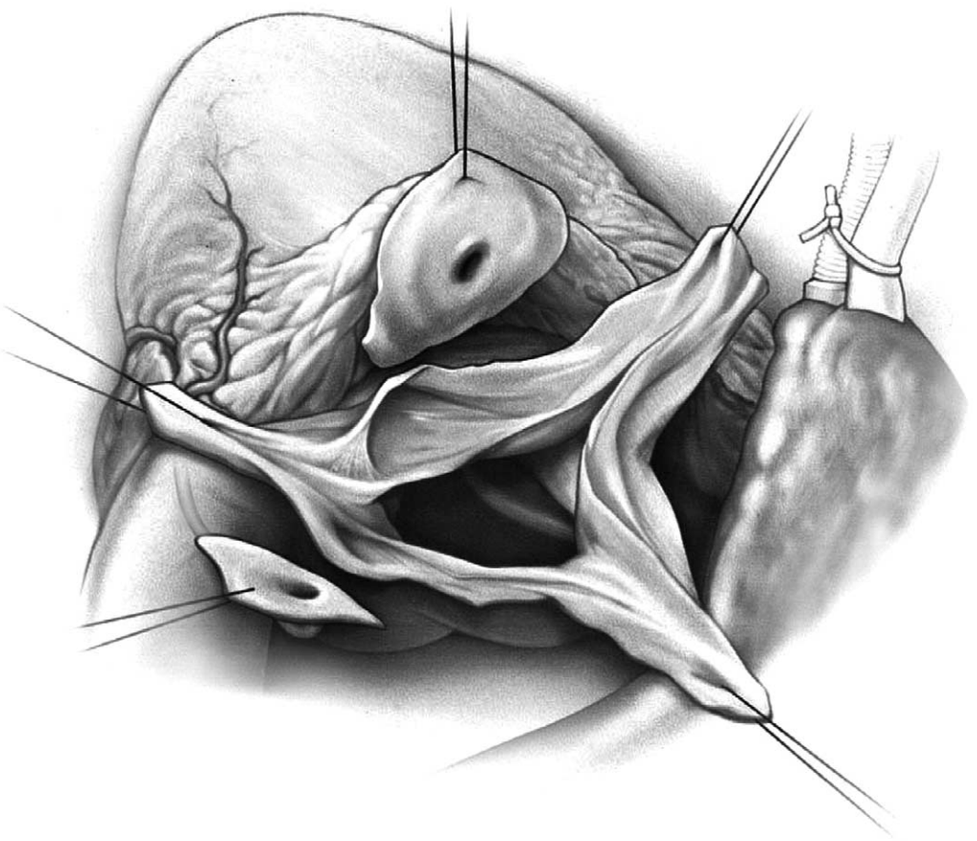

Figure 5 The sinuses are now excised, leaving about 4- to 5-mm sinus remnant along the annulus. Stay sutures of 4-0 Prolene are placed atop the coronary artery buttons to retract them from the surgical site and to maintain their proper orientation. If the root has been adequately mobilized, there should be excellent exposure. Each coronary is mobilized for 1 to1.5 cm.

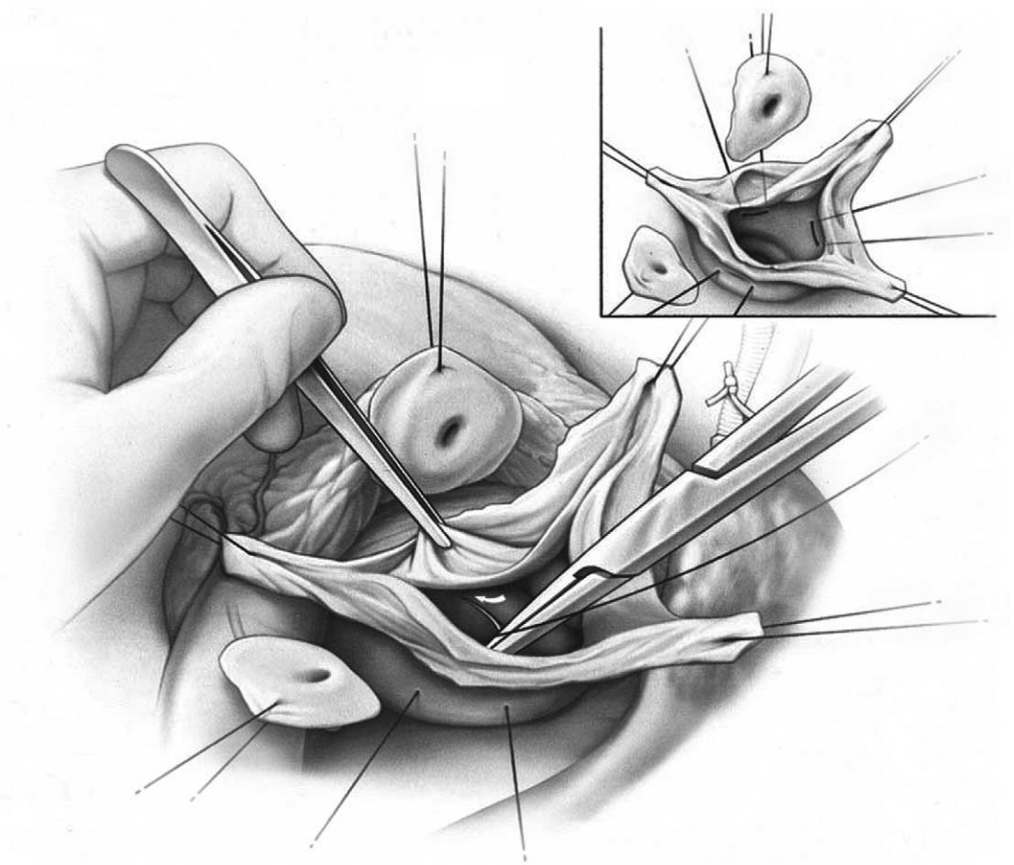

Figure 6 Three horizontal mattress sutures of 2-0 Tevdek are placed from within the left ventricular outflow tract directly below the nadir of each leaflet and out through the base of the aortic root; they are set into suture guides.

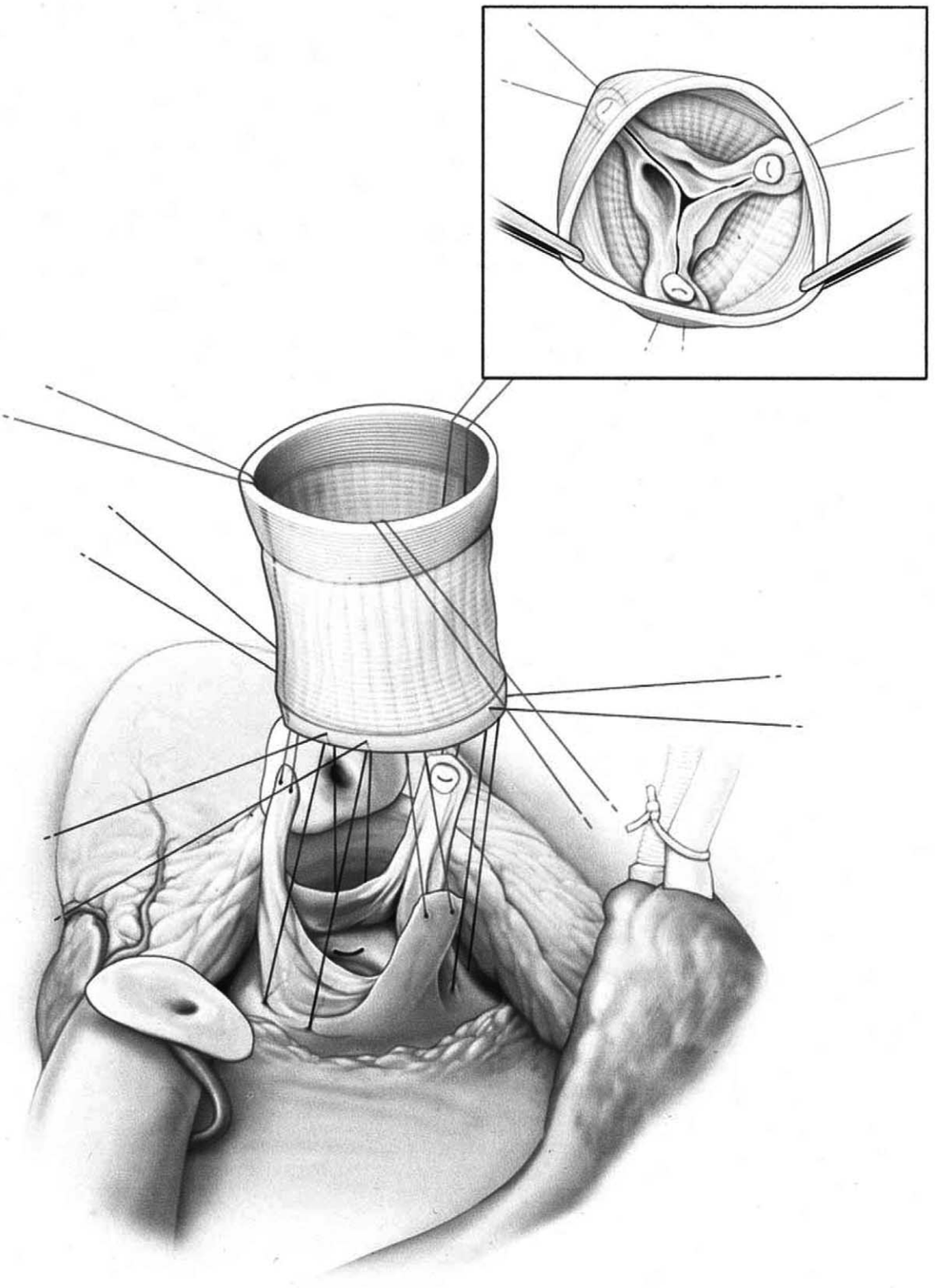

Figure 7 The subanular sutures are then placed through the base of the Valsalva graft. The three stay sutures at the tops of the commissures are drawn up through the graft and the graft is lowered. The three subanular sutures are tied. Three pledgetted 4-0 Prolene mattress sutures are next passed through the top of the three commissures and out through the sinotubular ridge of the graft. The three subanular and three commissural sutures are tied.

Next, the notches placed in two of the three black lines are repaired with pledgetted 2-0 Tevdek. These sutures also plicate the annulus somewhat and reduce anular diameter, but they are equally important for hemostatis and anular stabilization.

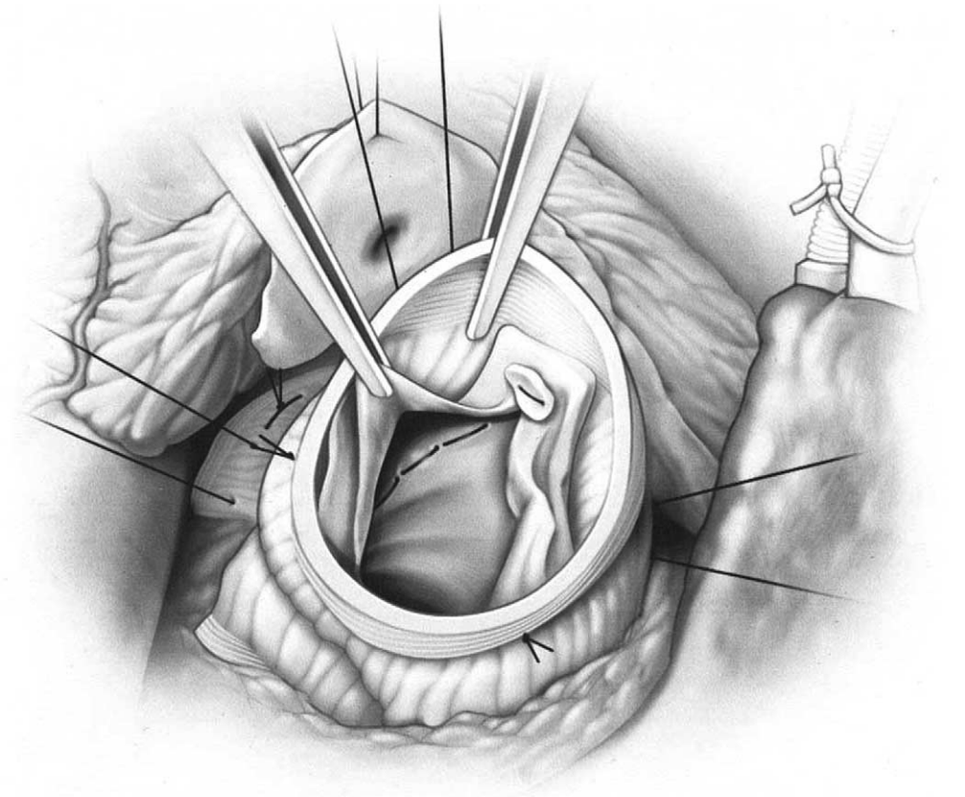

Figure 8 At this point, the root is now oriented within the graft. If there is marked anular dilation, additional subanular sutures can be placed, but in most of our patients we only place three. This simple "three in the bottom, three in the top" fixation of the valve within the graft avoids the complexity of guessing where the circumferential series of subanular sutures, which follow a "king's crown" course up and down from commissure to leaflet nadir, should be passed through the graft.

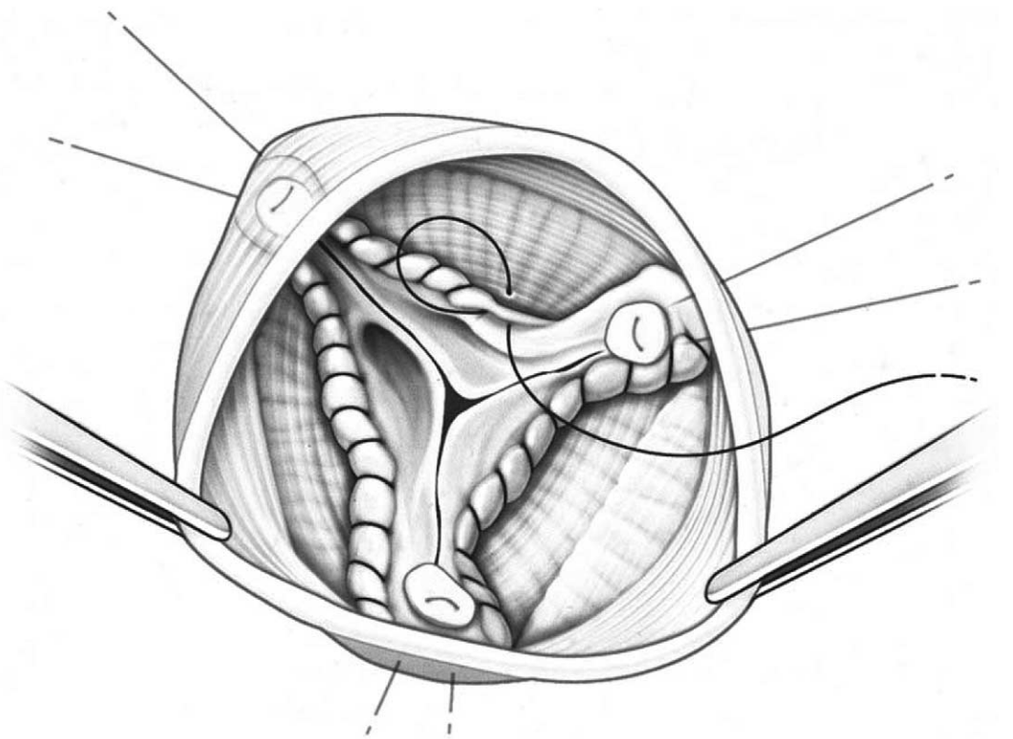

Figure 9 Attention is now directed to the hemostatic suture line within the graft. Beginning at the nadir of the left coronary sinus and sewing upward toward each commissure, a continuous 4-0 Prolene suture is used to fix the annulus and sinus remnant within the graft. It is useful for the assistant to provide traction at the top of the commissure to straighten the tissue–graft interface. The assistant is also charged with protecting the valve leaflet from injury.

The noncoronary sinus suture line is completed next, followed by the right coronary sinus. The 4-0 Prolenes are brought out and tied to one another outside the graft.

Inspection of the valve within the graft and filling the root with saline should demonstrate a competent valve. Malposition of the commissure or distortion of the annulus can lead to poor leaflet coaptation and regurgitation. Leaflet prolapse, in our view, is best treated by folding the midportion of the free leaflet edge using a pericardial pledget and 5-0 Tevdek mattress sutures to assure that all three leaflets have the same free edge length.

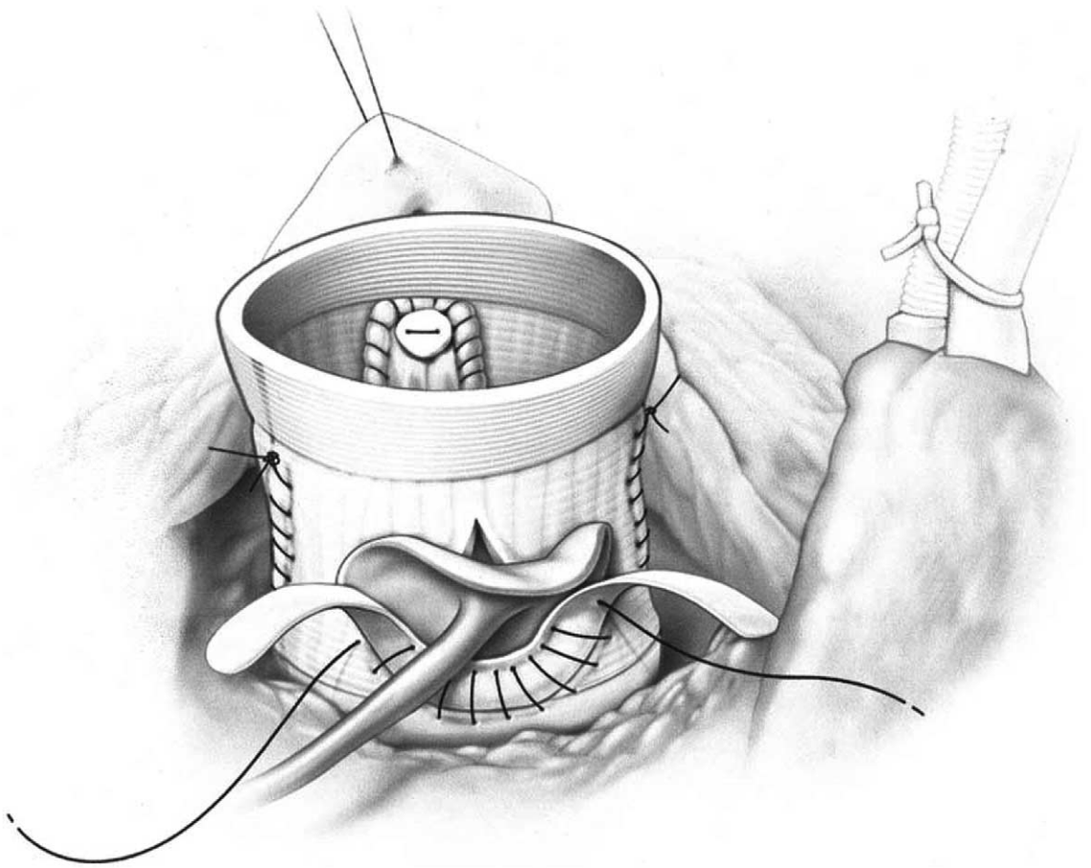

Figure 10 A hole approximately 6 to 7 mm in diameter is made in the middle of the left coronary sinus of the graft. The left coronary nearly always aligns perfectly with this position. We use 4-0 Prolene and a Teflon felt "lifesaver" circular pledget for hemostasis and prevention of late anastomotic pseudoaneurysm.

Positioning the right coronary anastomosis is always more challenging than the left. Our "rule of thumb" is to make the hole in the right coronary sinus as far anterior as possible and just below the sinotubular ridge of the graft. Alternatively, one can complete the distal aortic anastomosis, release the cross clamp briefly, and choose a site for implantation, but this leaves the aortic valve at some risk for inadvertent injury during creation of the hole in the graft. The right coronary anastomosis is likewise performed with 4-0 Prolene and an external felt washer.

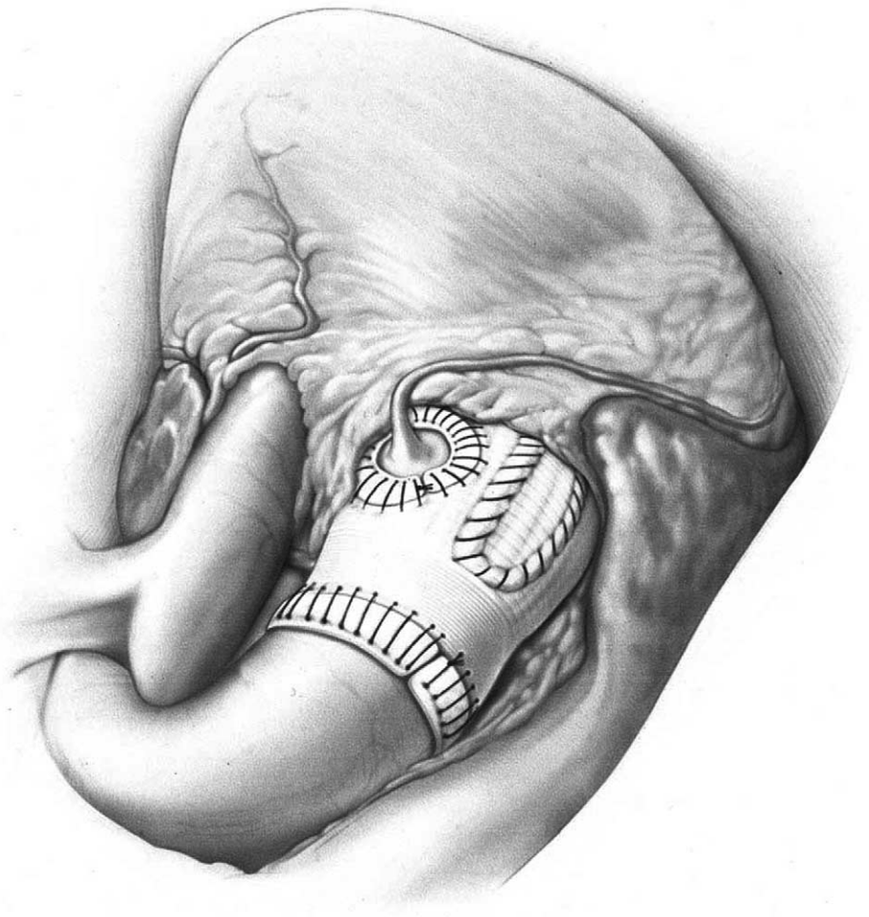

Figure 11 As the patient is warmed, the left atrial vent is exchanged for a left ventricular vent to adequately decompress the left ventricle during the early phase of resuscitation. The aortic anastomosis is also performed with 4-0 Prolene and an external felt strip.

We lower the oxygen tension of the perfusate to 100 Torr, administer lidocaine (200 mg), and release the cross-clamp. The rapidity of coronary perfusion is checked as well as the volume of left ventricular vent return and ventricular dilation. A de-airing site is created on the aorta, and the heart is given approximately 10 to 15 minutes of reperfusion for every hour of cross-clamping before taking volume and letting the ventricle eject.

Maneuvers for de-airing, removing vents, weaning from bypass, and decannulation follow the standard steps of open cardiac repair. Transesophageal echocardiography is invaluable for assessment of the valve competence; aortic insufficiency more than 1+ when off cardiopulmonary bypass completely should prompt re-arrest of the heart and revision of the repair, conversion to a Bentall-type operation, or valve replacement within the Valsalva graft. We favor the Bentall if bleeding appears problematic or if the graft is a small one (<28 mm).

Bleeding is much less with the reimplantation than with the remodeling procedure but may still be challenging. Aside from the coronary and distal aortic suture lines, bleeding is sometimes seen at the graft notches, which are easily reinforced, but sometimes at the base of the graft in the noncoronary sinus. Pledgetted sutures control these sites, which are accessible.

Postoperative Care

Patients are maintained on beta-blockers and aspirin for 1 month. Marfan syndrome patients remain on beta-blockers indefinitely. A predischarge echocardiogram is obtained, and annual exams are recommended thereafter. We recommend antibiotic prophylaxis for endocarditis, because most patients have trivial or mild aortic insufficiency.

Though no patient in our series of Valsalva graft patients has thus far required reoperation for late valve incompetence, a limited experience (three patients) with reoperation for aortic insufficiency after remodeling operations has shown that the procedure is usually straightforward. The distal aorta can be cannulated; the graft can be clamped and opened obliquely, and the valve can be excised. Mattress sutures through the base of the graft and then through the sewing ring of the valve prosthesis can be placed fairly easily. Choice of the valve prosthesis size differs from the usual circumstance of choosing the largest prosthesis that will fit within the annulus, whereas in this situation the valve and its sewing ring must fit comfortably within the Dacron conduit.

Conclusions

Valve-sparing aortic root replacement can be a technically challenging operation and should probably be limited to surgeons already comfortable and proficient with Bentall proce-

dures. The Valsalva graft can be used in the reimplantation procedure with the simplified operative technique described above. The critical step is sizing the graft, which we believe rests mainly on an intraoperative judgment of optimal sinotubular junction diameter for leaflet apposition. Whether the Valsalva graft fulfills the promise of lesser leaflet stress and therefore greater durability of valve competence must await long-term results.

Suggested Reading

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